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SUSCEPTIBILITY OF *Oryctes rhinoceros* BEETLE TO TRUNK-INJECTED ACEPHATE AND TRUNK-IMPLANTED ACEPHATE CONTROLLED-RELEASE INSECTICIDE ON TALL PALMS VIA PETIOLE BIOASSAY

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ABSTRACT

The Oryctes rhinoceros beetle (ORB) poses a significant threat to the oil palm industry, especially to young palm trees. These ORBs feed on the cabbage and spear parts of the palms, causing substantial growth damage. Although ORB infestations are less common in fully-grown tall palms, they still occur, especially in fields adjacent to immature palms. The traditional method of using insecticide sprays has proven to be difficult and impractical due to the towering height of the palm trees. To address this challenge, a new approach was explored, which includes injecting acephate soluble powder insecticide (acephate SP) into the palm trunks and implanting acephate trunk-implant-controlled-release insecticide (acephate TIMCRI). The efficacy of this method was compared to the spraying application of cypermethrin and broadcasting application of carbofuran and carbosulfan granular insecticides using a petiole bioassay method. In the petiole bioassay, adult ORBs were forced to feed on frond petioles from treated and untreated palms, and subsequent mortality and borehole volume were assessed. The results demonstrated that all treatments, including acephate SP, acephate TIMCRI, cypermethrin, carbosulfan, and carbofuran, exhibited satisfactory corrected mean mortality above 75% on ORBs at 14 days after treatment (DAT). Only acephate TIMCRI controlled-release formulation at 22.5 g a.i. per palm was able to prolong the period of control up to 35 DAT. Considering the limited control options available for ORBs in tall palms, trunk injection treatment of acephate SP and trunk implantation of acephate TIMCRI could be valuable alternatives to pest management strategies for mitigating the threat of ORB infestations on tall and mature oil palm plantations.

Keywords: Oryctes rhinoceros beetle, acephate SP, acephate TIMCRI, trunk injection, trunk implantation, mature oil palm

ABSTRAK

Kumbang Badak Oryctes rhinoceros (ORB) memberikan ancaman besar kepada industri kelapa sawit, terutamanya terhadap pokok kelapa sawit muda. ORB ini memakan bahagian pangkal dasar pokok dan pucuk kelapa sawit, menyebabkan kerosakan pertumbuhan yang signifikan. Walaupun infestasi ORB kurang berlaku pada pokok kelapa sawit yang sudah dewasa, namun ia masih berlaku terutamanya di ladang yang bersebelahan dengan kelapa sawit yang belum matang. Kaedah kawalan terkini yang menggunakan semburan racun serangga terbukti sukar dan tidak praktikal disebabkan ketinggian pokok kelapa sawit yang sukar dicapai untuk semburan dilakukan. Untuk mengatasi cabaran ini, pendekatan baru telah diterokai, termasuk menyuntikkan larutan racun serangga serbuk terlarut acephate (acephate SP) ke dalam batang kelapa dan juga meletakkan racun serangga pelepasan terkawal implan-batang acephate pada batang kelapa sawit (acephate TIMCRI). Keberkesanan kaedah ini dibandingkan dengan penyemburan racun serangga cypermethrin dan aplikasi racun serangga butiran carbofuran dan carbosulfan menggunakan kaedah ujian bioasai pangkal pelepah daun. Dalam kaedah ujian bioasai pangkal pelepah daun ini, ORB dewasa dipaksa untuk memakan pelepah dari kelapa yang dirawat dan yang tidak dirawat, dan kematian serta jumlah lubang yang terhasil dinilai. Keputusan menunjukkan bahawa semua rawatan, termasuk acephate SP, acephate TIMCRI, cypermethrin, carbosulfan, dan carbofuran, menunjukkan kematian purata yang memuaskan melebihi 75% pada ORB pada 14 hari selepas rawatan (HLR). Hanya formulasi racun serangga pelepasan terkawal implan-batang acephate TIMCRI pada 22.5 g a.i. per pokok kelapa sawit yang mampu memanjangkan tempoh kawalan sehingga 35 HLR. Mengambil kira pilihan kawalan yang terhad bagi ORB pada pokok kelapa sawit yang tinggi, rawatan suntikan batang acephate SP dan aplikasi racun serangga pelepasan terkawal implan-batang acephate TIMCRI boleh menjadi alternatif yang sesuai dalam strategi pengurusan serangga untuk mengurangkan ancaman infestasi ORB pada pokok kelapa sawit yang tinggi dan matang.

Katakunci: Kumbang badak *Oryctes rhinoceros*, acephate SP, acephate TIMCRI, suntikan batang, implan-batang, kelapa sawit matang

INTRODUCTION

The *Oryctes rhinoceros* (ORB) beetle is one of the major pests that cause severe damage to the growing points of immature palms (Bedford 2013; Ho 2010). ORB attacks caused growth setbacks and delayed maturity within the initial two years and losses reached 53% in the first year of harvesting (Chung et al. 1999). These ORBs feed on the cabbage and spear parts of the palms, causing considerable damage to the growing points. Although ORB attacks are less frequent in tall and mature palms, they do occur, especially in those adjacent to immature palms. According to Widihastuty et al. (2021), *Myopopone castanea* was recorded as their natural predator of *O. rhinoceros* during the immature stages by the interaction between *M. castanea* and *O. rhinoceros* larvae through the semiochemical compounds in rotting oil palm stems as a medium. However, the conventional control method of spraying insecticides has proven to be challenging and inefficient, primarily due to the towering height of the palm trees. A novel alternative approach was explored, involving trunk injection of acephate soluble powder insecticide (acephate SP) and trunk implantation of acephate trunk-implant-controlled-release insecticide (acephate TIMCRI). The trunk injection method involves the injection of insecticides directly into palm trunks, which then transport the insecticides through their conductive tissues to the site of action (Harrell 2006; Doccola et al. 2011; Mendel 1998; Mota-

Sanchez et al. 2009). Trunk implantation is a new method of inserting a specially formulated tablet consisting of a systemic insecticide in a drilled hole in the palm trunk whereby the active ingredients will be released in a controlled manner into the palm canopy with similar translocation via the conductive tissues. The efficacy of this method was compared to the spraying application of cypermethrin and the broadcasting application of carbofuran and carbosulfan granular insecticides. The comparison is necessary as these insecticides are used as a standard practice by the oil palm plantation companies to control the ORB.

Acephate is an organophosphate systemic insecticide used to control sucking and biting insects by direct contact or ingestion (Christiansen et al. 2011; Tomlin 2016; Thomson 1989). Acephate controls insect pests by inhibiting the enzyme acetylcholinesterase in nervous system tissues (Reigart & Roberts1999). Cypermethrin insecticide used for the control of ORB is non-systemic, it only remains on the exterior of the plant and must be in contact and absorbed through the body of the insect and may also act as a poison in the insect's stomach. It attacks the nervous system of the insects and interacts with the sodium channel in the insects, thus affecting neuron function (Macbean 2012). Ho (2010; 1988) and Abu Hassan (2006) reported that a controlled-release formulation of carbosulfan (at 12 g or 20 g per palm) was effective in controlling ORB in young oil palms. In another study, Abu Hassan (2006) also reported that carbosulfan provided 10 weeks of ORB control. Thus, the objective of this research was to evaluate the efficacy of these several insecticides to control *Oryctes rhinoceros* beetle on tall palms via the petiole bioassay method.

MATERIALS AND METHODS

Sampling Site

The field research was conducted at a 7-year-old oil palm field in an oil palm plantation estate in Labis, Johor, Malaysia (GPS Coordinate: 2°22'31.44" N and 103°2'40.199" E), whereby the plot was adjacent to an immature palm infested by ORB. In addition, the petiole bioassay study was conducted at the Insectary and Bioassay Laboratory, R&D Crop Protection, SD Guthrie Research Sdn Bhd, Banting, Selangor, Malaysia (GPS Coordinate: 2°48'13.6794" N and 10°27'36.3594" E).

Field Treatment

Trunk injection, trunk implantation, spraying and granular application treatment based on the treatment list in Table 1 were conducted on 7-year-old mature oil palm with five replications (one palm per replicate). All the insecticides were obtained from local dealers and pesticide companies. The dosage used for cypermethrin, carbosulfan and carbofuran were based on the label recommendations while for the acephate soluble powder and acephate TIMCRI dosages were based on the earlier bioassay studies conducted by the author (Meor 2018) and reference to Kellar and Cheng (2016) studies. The treatments included minimum dosage, twice (2X) the concentration (except for cypermethrin) and triple (3X) the concentration (for acephate only).

Table 1. List of Treatments and Methods

Treatment (Insecticide–Formulation Type)	**Dosage/ Palm**	**A.I. Gram / Palm**	**Application Method**	**Assessment Days**
Acephate 75%w/w Soluble Powder (SP)	20 g	15 g	Trunk Injection	Assessment Conducted At 1, 8, 14, 35, 56 and 84 Days After Treatment (DAT)
Acephate 75%w/w Soluble Powder (SP)	40 g	22.5 g	Trunk Injection	
Acephate 75%w/w Soluble Powder (SP)	60 g	30 g	Trunk Injection	
Acephate TIMCRI 62.5% w/w Tablet (T)	1 Tablet	15 g	Trunk Implantation	
Acephate TIMCRI 62.5% w/w Tablet (T)	1 Tablet	22.5 g	Trunk Implantation	
Acephate TIMCRI 62.5 % w/w Tablet (T)	2 Tablets	30 g	Trunk Implantation	
Cypermethrin 5%w/w Emulsifiable Concentrate (EC)	3 ml	0.15 g	Spraying on Spear Base and First Spiral of Fronds	
Carbosulfan 18.7%w/w Suspension Concentrate (SC)	0.75 ml	0.15 g	Spraying on Spear Base and First Spiral of Fronds	
Carbosulfan 18.7%w/w Suspension Concentrate (SC)	1.5 ml	0.30 g	Spraying on Spear Base and First Spiral Of Fronds	
Carbosulfan 5%w/w Granular (G)	12 g	0.06 g	Applied At Spear Base	
Carbosulfan 5%w/w Granular (G)	48 g	0.24 g	Applied At Spear Base	
Carbofuran 3%w/w Granular (G)	30 g	0.09 g	Applied At Spear Base	
Carbofuran 3%w/w Granular (G)	120 g	0.36 g	Applied At Spear Base	
Untreated Ctrl (Negative Control)	-	-	-	

Petiole Bioassay Methods

After the treatment, at 24 hours after the treatment, for the first day of assessment (one day after treatment (1 DAT), one frond near the spear base (first spiral of fronds) was cut down for the petiole bioassay assessment. Adult beetles were forced to feed near the surface bases of petioles by enclosing them individually in one-inch diameter blocks of wood attached by screws. Two blocks (for 1 male ORB and 1 female ORB) were attached to each petiole. The hard petiole surface at the bottom of each hole was abraded to a depth of about 1 mm to help beetles start their boreholes. After seven (7) days of confinement in an air-conditioned laboratory, beetles were removed to check for mortality. Feeding damage was assessed by pouring water into each borehole and measuring its volume (Moore 2008). This was conducted at 1,8,14,35, 56 and 84 days after treatment (DAT). Images of the assessment are displayed in Figure 1 below.

Figure 1. Petiole Bioassay method

Experimental Design and Statistical Analysis

The experimental design was a Randomised Complete Block Design (RCBD) with 5 replicates. All mortality data were converted into mortality percentages based on Schneider-Orelli's formula and analyzed for one-way ANOVA to detect the differences between treatment effects and the means were compared using Tukey's HSD Test. The ORB mean mortality percentage data was summarized to determine the effectiveness level of the insecticides in Table 2 below.

Table 2. Insecticide Effectiveness Description Scale Rating

Mean Mortality Percentage	Insecticide Effectiveness Description
0%	No insecticidal effect of the insecticide on the insect pest
1%-24%	Poor to low insecticide effectiveness on the insect pest
25%-49%	Low to moderate insecticide effectiveness on the insect pest
50%-74%	Moderate to satisfactory insecticide effectiveness on the insect pest
75%-99%	Satisfactory to good insecticide effectiveness on the insect pest
100%	Excellent insecticide effectiveness on the insect pest

Modified from Erick et al. (2000) and JPPA (2011).

RESULTS AND DISCUSSION

Observation on ORB Petiole-Boring Activity

All the ORB showed signs of petiole boring activity with borehole occurring in the petiole with an average volume varying between 5 to 8 ml/hole. These indicated that the adult ORB had managed to consume the treated petiole with the insecticides in the treatment list. The ORB bored into the petiole to suck the sap juices, this activity mimics the infestation that occurred in the immature palms whereby beetle bores into the base of the cluster of unopened fronds (spears) of the young oil palms and creates holes (Norman & Basri 1995; Gressit 1953).

Petiole Bioassay Results

The petiole bioassay results (Table 3) demonstrated that all treatments, including acephate SP, acephate TIMCRI cypermethrin, carbosulfan, and carbofuran, exhibited satisfactory corrected mortality rates above 75% on ORBs at 14 DAT. These results aligned with the findings of Kellar and Cheng (2016) who discovered acephate showed high mortality at 14 days after treatment (DAT) at laboratory bioassay. The effectiveness of cypermethrin, carbosulfan and carbofuran aligned with the earlier findings for ORB control (Abu Hassan 2006; Ho 2010; Ho 1988)). In addition, only acephate TIMCRI slow-release formulation at 22.5 g a.i. per palm was able to prolong the period of control up to 35 DAT. It was also observed that acephate TIMCRI provided good early mortality (80%) on ORB at 8 DAT, however, it was not significantly different than other treatments except against the untreated. Considering the limited control options available for ORBs in tall palms, as spraying and granular application is difficult and tedious, the trunk injection treatment of acephate SP and trunk implantation of acephate TIMCRI would be suitable alternatives to pest management strategies for mitigating the threat of ORB infestations on tall and mature oil palm plantations. In addition, the use of

trunk injection and trunk implantation methods has minimal impact on beneficial insects and pollinating weevils since it is a close-end treatment with no exposure to non-targeted pests. The trunk injection technology is a more environmentally friendly method of applying insecticides, because it is highly efficient for liquid systemic insecticides, is relatively pollution-free, safe, simple to apply, and is less affected by weather (Navarro 1992; Montecchio 2013). The use of acephate through trunk injection or trunk implantation posed no significant health risk to consumers because no detectable levels of the residues were found in crude palm oil (CPO) and crude palm kernel oil (CPKO) from fresh fruit bunches harvested from oil palms treated with acephate as reported in a study conducted by Yeoh and Ainie (2015). In another study, results from laboratory-scale palm oil refining experiments suggested that the commercial refining process is capable of effectively removing acephate residues (virtually up to 100% after the full refining process) from CPO (Yeoh & Chong 2009).

Table 3. Mortality of the *Oryctes rhinoceros* Beetle

Treatment	Active Ingredient (a.i.)	Corrected Mean Mortality – Combined Male and Female *Oryctes rhinoceros Beetle* (ORB) (%) (Schneider-Orelli's formula) (After 7 Days of Force Feeding)					
(Insecticides & Formulation Type)	gram / palm	1 DAT	8 DAT	14 DAT	35 DAT	56 DAT	84 DAT
Acephate 75% w/w SP	15	37.78 ± 18.46 a[z]	37.78 ± 18.46 ab	88.89 ± 11.11 a	22.50 ± 9.19 b	55.00 ± 19.61 b	37.78 ± 18.46 a
Acephate 75% w/w SP	22.5	44.44 ± 0.00 a	37.78 ± 18.46 ab	88.89 ± 11.11 a	22.50 ± 9.19 b	15.00 ± 9.19 b	46.67 ± 15.87 a
Acephate 75% w/w SP	30	35.56 ± 8.89 a	26.67 ± 10.89 ab	88.89 ± 11.11 a	30.00 ± 7.50 b	47.50 ± 22.50 b	17.78 ± 10.89 a
Acephate TIMCRI 62.5 % w/w T	15	37.78 ± 18.46 a	40.00 ± 24.50 ab	88.89 ± 11.11 a	42.50 ± 16.11 b	55.00 ± 19.61 b	8.89 ± 8.89 a
Acephate TIMCRI 62.5 % w/w T	22.5	17.78 ± 10.89 a	80.00 ± 20.00 a	77.78 ± 13.61 a	75.00 ± 15.31 a	42.50 ± 16.11 b	35.56 ± 8.88 a
Acephate TIMCRI 62.5 % w/w T	30	28.89 ± 19.75 a	26.67 ± 10.89 ab	88.89 ± 11.11 a	62.50 ± 15.31 b	15.00 ± 9.19 b	37.78 ± 18.46 a
Cypermethrin 5% w/w EC	0.15	28.89 ± 19.75 a	66.67 ± 13.61 ab	77.78 ± 13.61 a	47.50 ± 22.50 b	37.50 ± 0.00 c	26.67 ± 10.89 a
Carbosulfan 18.7% w/w SC	0.15	48.89 ± 22.39 a	26.67 ± 10.89 ab	77.78 ± 13.61 a	15.00 ± 9.19 b	50.00 ± 12.50 b	37.78 ± 18.46 a
Carbosulfan 18.7% w/w SC	0.30	8.89 ± 8.88 a	48.89 ± 22.39 ab	77.78 ± 13.61 a	27.50 ± 19.53 b	42.50 ± 16.11 b	8.89 ± 8.88 a
Carbosulfan 5% w/w G	0.06	35.56 ± 8.89 a	55.56 ± 11.11 ab	88.89 ± 11.11 a	47.50 ± 22.50 b	30.00 ± 7.50 b	26.67 ± 10.89 a
Carbosulfan 5% G	0.24	17.78 ± 10.89 a	68.89 ± 20.31 ab	77.78 ± 13.61 a	62.50 ± 15.31 b	55.00 ± 19.61 b	28.89 ± 19.75 a
Carbofuran 3% G	0.09	57.78 ± 19.05 a	37.78 ± 18.46 ab	77.78 ± 13.61 a	55.00 ± 19.61 b	30.00 ± 7.50 b	40.00 ± 24.50 a
Carbofuran 3% G	0.36	20.00 ± 20.00 a	48.89 ± 22.39 ab	88.89 ± 11.11 a	30.00 ± 7.50 b	50.00 ± 12.50 b	28.89 ± 19.75 a
Untreated (Negative Conrol)	NA	0.00 ± 0.00 a	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 c	0.00 ± 0.00 b	0.00 ± 0.00 b

Note:
*Cells highlighted in yellow indicated satisfactory corrected mean mortality above 75%
[Z]Means within the same column followed by the same letter are not significantly different at P=0.05 based on Tukey HSD for each of the trials. All data were transformed into arcsine for statistical analysis and original data was used for presentation.

CONCLUSIONS

The study concluded that acephate soluble powder (SP), acephate trunk-implant-controlled release insecticide (TIMCRI), cypermethrin, carbosulfan soluble concentrate (SL), carbosulfan granule (G) and carbofuran granule (G) provided satisfactory effectiveness in causing mortality of *Oryctes rhinoceros* beetles on tall mature palms within 14 days after treatment. Notably, the controlled-release formulation of acephate TIMCRI at a rate of 22.5 grams of active ingredient per palm managed to extend the control period of ORB, maintaining effectiveness for up to 35 days after treatment. Based on the outcome of the study, trunk injection treatment of acephate SP at 15 g ai per palm and trunk implantation of acephate TIMCRI at 15 and 22.5 g active ingredient per palm is recommended for the treatment of *Oryctes rhinoceros* beetle in mature and tall palms since spraying treatment and granular application of carbofuran or carbosulfan is not practical for implementation. The recommendation is based on the proven effectiveness

of acephate formulation via both methods and the ease of treatment implementation for tall palms.

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AUTHORS DECLARATIONS

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Conflict of Interest

The authors declare that they have no conflict of interest.

Ethics Declarations

No ethical issue is required for this research.

Data Availability Statement

My manuscript has no associated data. Data is available from the author upon request.

Authors' Contributions

The conceptualization and analysis of this study was carried out by both authors. Both authors read and approved the final manuscript. The project was funded fully by SD Guthrie Research Sdn Bhd (*formerly known as Sime Darby Plantation Research Sdn Bhd*). The authors declare that they have no conflict of interest and no violation of ethics in conducting and completing this study.

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